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ALTERNATE USES OF THE E.P.I.D.M. CHESTBAND: PORCINE STUDIES

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INTRODUCTION

Injury in the rural setting is a unique problem that has received little biomechanical attention. The role of biomechanics to understand the mechanism of injury in rural accidents will lead to preventive measures and enhanced safety. Although the fatality rate has decreased over the last 20 years, the percentage of tractor related fatalities has remained essentially the same since 1969 (National Safety Council, 1990). Of the tractor related fatalities between the years 1985 to 1989, 40% were rollover, 23% were runover injuries and 27% were other types of injuries (National Safety Council, 1990). A rollover accident constitutes the tractor or farm implement overturning at least one quarter or more turn. A runover injury is defined as the wheel of the tractor or machinery physically runs over a subject. One of the great problems in rural injury is that subjects after being injured remain in the field before emergency medical care arrives for over one and a half hours (Cogbill and Bush, 1985). Although tractor wheel runovers constitute only 20% of farm related fatalities, a significant number of runovers occur with farm implement machinery as well. Perhaps the greatest tragedy of farm related accidents is that children under the age of 12 account for 25% of runover fatalities (McNight and Hetzel, 1985). In the present investigation a tractor wheel runover accident was simulated to obtain biomechanical information relating to mechanism of injury.

MATERIALS AND METHODS

A 1975 John Deere Tractor (Model 2520 HiCrop) was used to reproduce a traumatic tractor runover event. Seven porcine cadaveric specimens were used with anthropometric data summarized in Table 1. They were run over with the right front wheel of the tractor at approximately the level of the xyphoid process on the chest. The speed of the tractor was approximately 0.3 m/s and the front wheel had normal pressure of approximately 30 psi. The cadaveric porcine preparation was placed right side down on the six-axis force plate with the wheel path proceeding from the ventral to dorsal direction. The NHTSA chestband was fixed around the preparation at the level of wheel runover to obtain deformation information of the chest. The chestband was adhered to the specimen and protected externally using duct tape. Figure 1 shows a schematic diagram of the test setup. The chestband recorded 16 channels of information and the force plate recorded 6 channels of information. These 22 channels were sampled by a computer data acquisition system and downloaded for further analysis. Results from preliminary experiments indicated the necessity of a ramp 56 cm long and 14 cm high abutting the porcine specimen. This ramp insured a complete runover of the preparation. The front legs of the specimen were also tied securely. As a simple check of the chestband deformations, a video camera set up perpendicular to the direction of wheel travel was used to record kinematic information. The wheel was marked with calibration squares and the overall maximum deformation of the preparation was obtained. The chestband was zeroed prior to and following each test to insure proper function. The R-BAND PC program was used to obtain the chest contours vs time throughout the runover event. Pathological information was obtained by conducting an autopsy.

TABLE 1

PORCINE SPECIMEN DATA

Number	Weight kg	L/R (cm)	AP Diameter (cm)	Circ (cm)
1	61	24	34	91
2	63	20	34	91
3	72	27	36	101
4	77	29	37	103
5	71	24	35	94
6	44	21	32	86
7	58	23	32	91

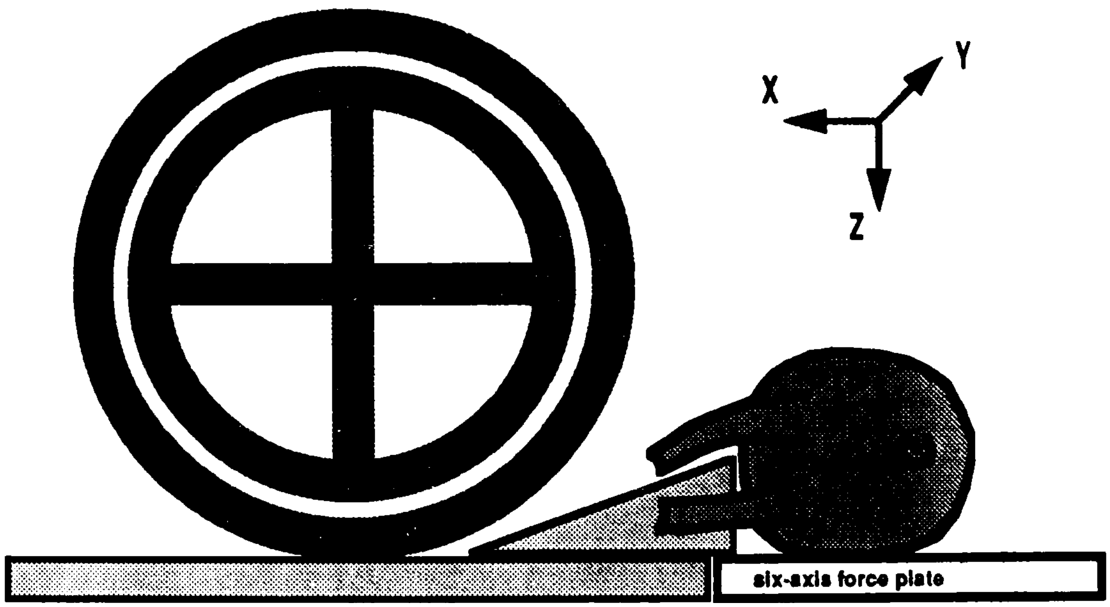

Figure 1: Schematic representation of experimental set-up for porcine wheel runover test. The orientation of axes is shown; the six-axis force plate was directly under the preparation. The front right wheel of the tractor (diameter: 76 cm) ran over the preparation in the chest region. A N.H.T.S.A. chestband was placed around the chest of the preparation directly under the path of the wheel.

RESULTS

Force plate information revealed that a significant portion of the force history was obtained from the x-axis (wheel path direction). These high shear forces occurred in the beginning of the runover where the tire was climbing over the preparation; negative shear forces occurred at the end of runover when the tire was falling off the preparation (Figure 2). These shear forces also produced trauma to the rib cage at the costo-vertebral junction. This was commonly seen as complete or partial dislocation of the rib from the vertebral body. There were often multiple fractures per rib in the area directly below the path of the tire. These fractures occurred in the mid portion of the rib and were presumed to be caused by the direct weight of the tire on the specimen. The chestband revealed the temporal sequence of the chest contours as the runover occurred. Figure 3 demonstrates a series of contours as the preparation is being run over. The contours revealed tremendous compressions in the first phase of the runover where tissue is being squeezed as the tire climbs. Maximum chest compressions recorded by the chestband ranged from 45 to 68% with a mean of 55 ± 11%. Video motion analysis revealed maximum chest compressions in the range of 45 to 71% with a mean of 57 ± 10%. The video photographic analysis indicates an accurate performance of the chestband.

DISCUSSION

To the best of our knowledge this has been the first time that the NHTSA Chestband Device has been used to obtain measurements in rural runover injury simulations. The chestband performed remarkably well considering the severity of the test environment. Because of data acquisition restraints a maximum of 16 channels of chestband information was obtainable. In the automotive crash environment previous studies have recommended the use of at least 24 gauges of information to reproduce reliable chest contours (Hagedorn, et. al., 1990). However, these earlier results are based upon smaller radius' of curvature, approximately 3". In the present

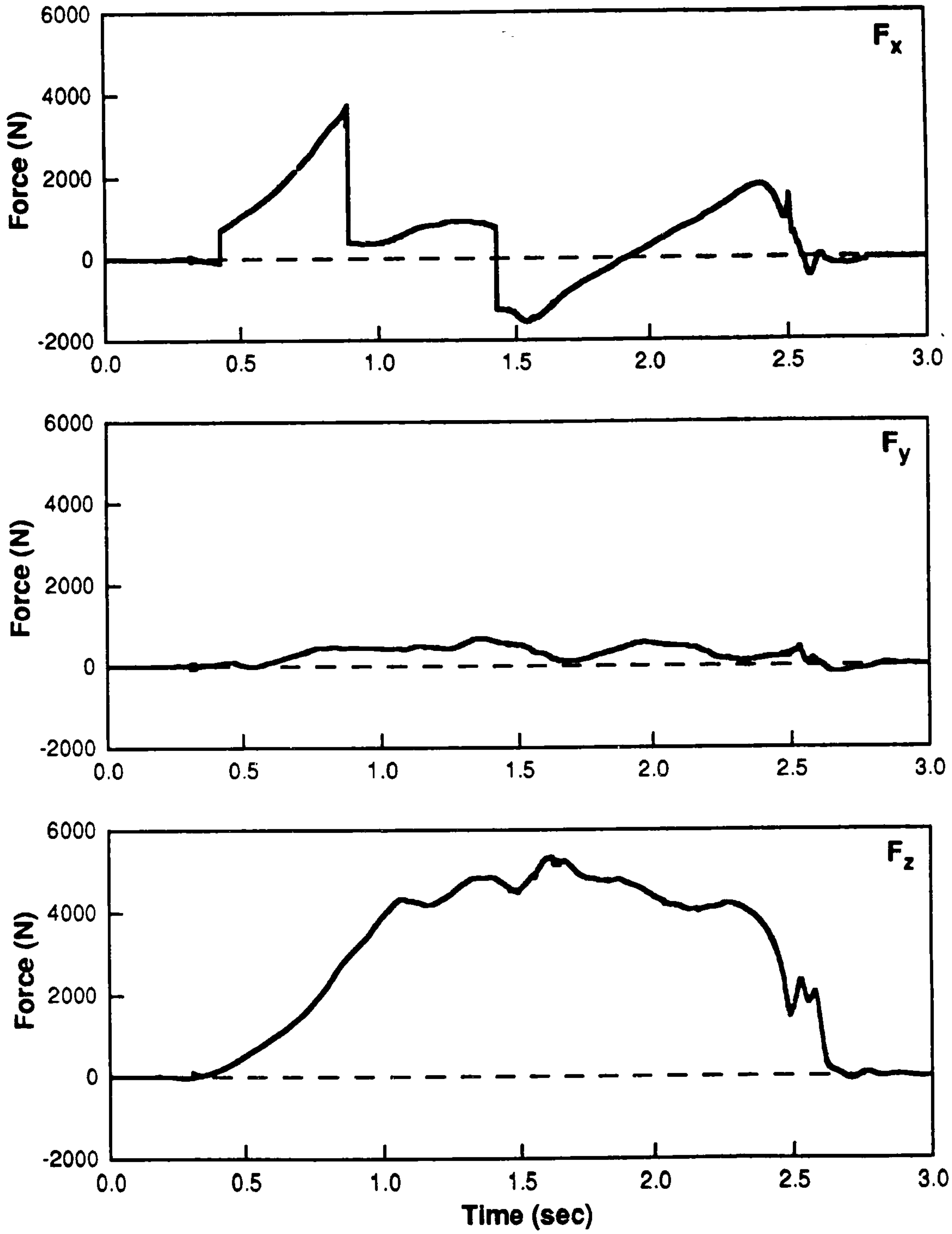

Figure 2: Linear forces recorded by the force plate during specimen 7 wheel runover experiment. Note the high Fx shear force recorded initially when the wheel pushes and climbs the preparation.

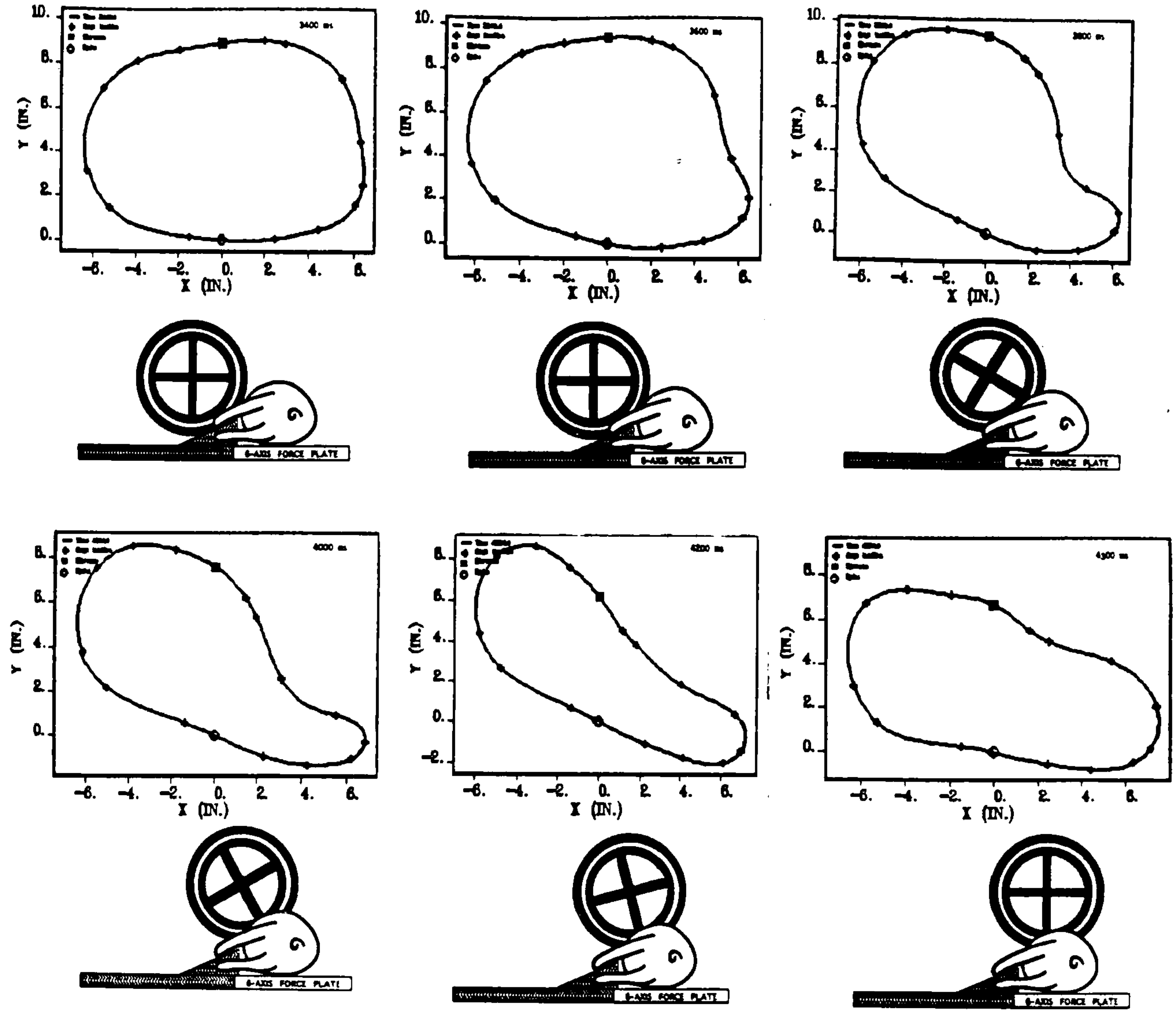

Figure 3: A series of chestband contours from porcine specimen test 7. The series starts at 3400 ms just prior to wheel contact and proceeds to 4300 ms. The orientation of the chest contours is such that ventral is on the right the left side of the preparation is toward the top. The schematic diagram below indicates the approximate location of the wheel during the event. Note the significant compressions recorded at 4000 and 4200 ms when the wheel climbs the preparation.

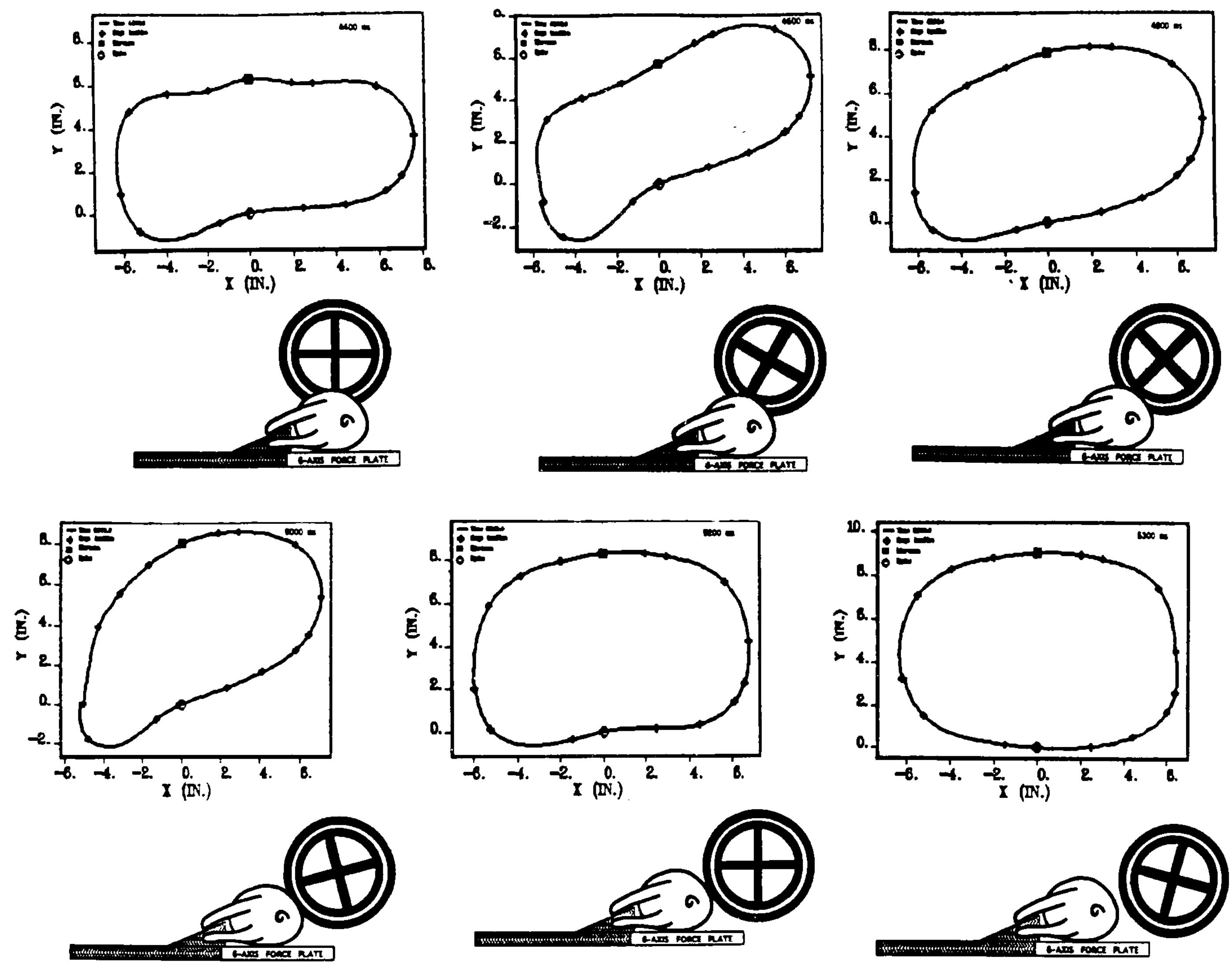

Figure 3: A series of chestband contours from porcine specimen test 7. The series continues from 4400 ms when the wheel is almost on top of the preparation and proceeds to 5300 ms when the wheel is no longer in contact. The orientation of the chest contours is such that ventral is on the right the left side of the preparation is toward the top. The schematic diagram below indicates the approximate location of the wheel during the event. Note that the final contour is virtually identical to that prior to the event.

study we used a tractor tire with a 15" radius to apply the loading on the preparation. Our video analysis check of the maximum chest compressions revealed good agreement between photographic and chestband output. Thus, with larger diameter impacting surfaces a 16" channel chestband seems appropriate to obtain accurate contours.

Another interesting finding in the results was the contribution of shear forces (F_X) to the pathological results. These shear forces cause distinct partial or complete dislocation at the costo-vertebral junction. These injuries may be severe enough to sometimes cause lung puncture by the rib.

Biomechanical information revealed tremendous compressions of the chest up to 68%. Even with these drastic compressions the soft tissue was not damaged. The most severe soft tissue injuries were due to displaced rib fractures puncturing the lung. Contusion and hematoma of the surrounding muscular and fat tissue associated directly with the multiple rib fractures was also noted.

In conclusion, the NHTSA Chestband performed well under the harsh scenario of the tractor runover incident. Because of the nature of the contact surface, 16 channels of chestband was adequate to measure chest deformation contours. The chestband is a unique device to measure temporal deformation contours of the chest and offers new biomechanical information concerning trauma to the subject of a tractor runover test.

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DISCUSSION

PAPER: **Alternate Uses of the EPIDM (Chest Band)**

PRESENTER: Frank Pintar

FELLOW AUTHORS: Y. King Liu, N. Yoganandan, J. Winterbottom and A. Sances, Jr.

QUESTION: John States, University of Rochester
Can you describe the tire and the wheel and the load and the tire pressure and what the tire was like under a particular tractor?

ANSWER: Not knowing tractor tires all that well, I mean I don't have that much experience with different types of tractor tires, from what I understand, it was the typical tractor wheel that would be used in this kind of rollover and we didn't inflate it or deflate the tire pressure any more or less.

Q: This was not a driven wheel I gather. In other words, the ribs were circumferential and not diagonal, the tread ribs?

A: Correct. Yes.

Q: And do you know what the pressure of the tire was?

A: I don't know offhand.

Q: What was the load on that individual wheel? You said the tractor weighed three thousand kilograms.

A: Yes. We did do tests of just the tractor running over the force plate without anything there and we found that the loads with just the wheel alone were somewhere around twelve hundred pounds, which is close to what you get. The foreseen cadaver tests are just under that because you get that contribution of the sheer force.

Q: How many wheels does it have?

A: It has four wheels.

Q: Sixty six hundred pounds?

A: Yes. There is more weight on the back wheels. Am I right, King?

A: Yes.

A: And this was a front wheel.

Q: It would be great if you would find the tire pressure and a lot of additional information and the equilibrium on the loads I'm discussing.

A: Hm.

Q: Just a comment. I think this is a fruitful area to work in. I've had patients who have been run over by tractors and it is amazing what does not happen to them and I think if we control tire pressures and maybe modify tire design a little bit, we'll have even more survivals with much less injury. This is just the kind of research that needs to be done.

A: Yes. From what we've seen, there is just not a whole lot of data at all out there like this and certainly more has to be done. This is just baseline data.

Q: Thank you.

Q: Dave Viano, General Motors
I agree this is interesting research and some of the things we see with trucks, light duty trucks and farm trucks running over children, often times it is only when the child's head is run over, do we get a fatality. In the cases of the body, they tend to get pushed into the earth and do I assume that the load type was essentially a rigid support for the animal?

A: Yes. It was. Ideally, this would be good to do obviously in the field.

Q: Y. King Liu, University of Iowa
I just wanted to add a comment to what Dave Viano was saying that, if you recall, in the preliminary experiment on Cadaver No. 1, it was not a runover, it was a drag.

A: OK.

Q: In the drag instance, of course, FX keeps acting and FZ never got there but FX's was so high that that particular peak on autopsy produced the most massive injuries if my memory serves me correctly.

A: Very high injuries and we also got internal injuries on that one.

Q: So that further experimenting in which driving did take place, produced the most massive injuries.